PRELIMINARY REPORT

ON

HEAT-FLOW DRILLING IN WASHINGTON DURING 1981

by

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Olympia, WA 98504

Open-File Report 81-8

November, 1981

CONTENTS

	Page
Introduction	1
Description of units penetrated by drill holes	2
Scenic No. 1	2
Scenic No. 2	2
Snoqualmie No. 1	2
Snoqualmie No. 2	2
White River	3
Clear Creek	3
Sand Ridge	3
Tieton Willows	3
Trout Creek	4
Carson	4
Klickitat	5
North Bonneville Nos. 1, 2, and 3	5
References cited	7

ILLUSTRATIONS

Page

Figure 1. Location map for heat-flow drill holes, Cascade Range, 1981..... 9

2. Composite temperature-depth plots for Scenic No. 1, Scenic No. 2, Snoqualmie No. 1, Snoqualmie No. 2, and White River drill holes.. 10

3. Composite temperature-depth plots for Clear Creek, Sand Ridge, Tieton Willows, Trout Creek, Carson, and Klickitat drill holes 11

4. Composite temperature-depth plots for North Bonneville No. 1, North Bonneville No. 2, and North Bonneville No. 3 drill holes ... 12

5. Temperature-depth plot for Scenic No. 1 drill hole..... 13

6. Temperature-depth plot for Scenic No. 2 drill hole..... 14

7. Temperature-depth plot for Snoqualmie No. 1 drill hole 15

8. Temperature-depth plot for Snoqualmie No. 2 drill hole 16

9. Temperature-depth plot for White River drill hole..... 17

10. Temperature-depth plot for Clear Creek drill hole 18

11. Temperature-depth plot for Sand Ridge drill hole 19

12. Temperature-depth plot for Tieton Willows drill hole 20

13. Temperature-depth plot for Trout Creek drill hole 21

14. Temperature-depth plot for Carson drill hole 22

15. Temperature-depth plot for Klickitat drill hole 23

16. Temperature-depth plot for North Bonneville No. 1 drill hole 24

17. Temperature-depth plot for North Bonneville No. 2 drill hole 25

18. Temperature-depth plot for North Bonneville No. 3 drill hole 26

TABLES

Page

Table 1. Cascade Range temperature gradients from 1981 drilling 27

2. Geothermal temperature gradient measurements for Scenic No. 1 drill hole 28

3. Geothermal temperature gradient measurements for Scenic No. 2 drill hole 28

4. Geothermal temperature gradient measurements for Snoqualmie No. 1 drill hole 29

5. Geothermal temperature gradient measurements for Snoqualmie No. 2 drill hole 29

6. Geothermal temperature gradient measurements for White River drill hole 30

7. Geothermal temperature gradient measurements for Clear Creek drill hole 30

8. Geothermal temperature gradient measurements for Sand Ridge drill hole 31

9. Geothermal temperature gradient measurements for Tieton Willows drill hole 31

10. Geothermal temperature gradient measurements for Trout Creek drill hole 32

11. Geothermal temperature gradient measurements for Carson drill hole 32

12. Geothermal temperature gradient measurements for Klickitat drill hole 33

13. Geothermal temperature gradient measurements for North Bonneville No. 1 drill hole 34

14. Geothermal temperature gradient measurements for North Bonneville No. 2 drill hole 35

15. Geothermal temperature gradient measurements for North Bonneville No. 3 drill hole 36

INTRODUCTION

The Washington Division of Geology and Earth Resources, under contract to Ponderosa Drilling and Exploration, Inc. of Spokane, drilled 10 shallow temperature gradient-heat flow holes in the Cascade Range of Washington during the summer of 1981. The purpose of this report is to convey some of the preliminary results of this investigation. In addition, we report preliminary data from three holes drilled by the City of North Bonneville and one hole drilled near Snoqualmie Pass by Mr. David Dyer. The investigations are part of a Washington State geothermal resource assessment program supported by a contract from the U.S. Department of Energy, Division of Geothermal Energy.

Locations of drill holes, depths, dates drilled and logged, temperature gradients, generalized downhole lithologies, and other pertinent data are reported here. Additional interpretations, such as heat-flow values, and geothermal significance of the drill holes will be reported at a later date when further investigation has been completed.

Shallow heat-flow holes were drilled in the Cascade Range of Washington for two reasons:

(1) To obtain "regional" temperature gradient and heat-flow data in areas where there were no pre-existing wells. These data are incorporated into ongoing efforts to evaluate the geothermal resources of the Cascade Range. The Snoqualmie, White River, Clear Creek, Sand Ridge, and Tieton Willows holes were drilled for this purpose.

(2) To obtain subsurface data on rate of temperature increase, hydrology, and heat flow in the vicinity of known thermal springs. The Scenic, Trout Creek, Carson, Klickitat, and North Bonneville drill holes were drilled for this purpose, but they also contribute to the ongoing regional evaluations mentioned in (1) above.

The descriptions of downhole lithologies are modified from two reports by Kent and Associates, Consulting Geologists, Lake Oswego, Oregon, to the Washington Division of Geology and Earth Resources and to the City of North Bonneville.

DESCRIPTION OF UNITS PENETRATED BY DRILL HOLES

Scenic No. 1

The Scenic No. 1 drill hole penetrated granodiorite and quartz diorite for its full depth. Pratt (1958) assigned these rocks to the Mount Stuart batholith, a large granodiorite and quartz diorite intrusive which becomes locally gneissic in the Stevens Pass area. Potassium-argon ages range from 80 to 90 million years before present, with an average of 88 m.y. (Engels and Crowder, 1971).

Scenic No. 2

This drill hole penetrated landslide deposits to a depth of 33 meters. Quartz biotite schist was encountered from 33 to 82 meters, and the remainder of the hole was in biotite schist. The rock from 33 meters to the bottom of the hole is probably part of the Chiwaukum Schist, of Carboniferous age (Pratt, 1958).

Snoqualmie No. 1

This drill hole penetrated argillite with several phyllitic zones for its entire depth. These rocks are part of the Guye Formation, which consists of terrestrial carbonaceous mudstone, shale, sandstone, conglomerate, and breccia of Paleocene or Eocene age (Chitwood, 1976). The rocks penetrated by the drill hole are somewhat metamorphosed, presumably due to the proximity of the Snoqualmie batholith (Miocene) to the north.

Snoqualmie No. 2

The upper 25 meters of this drill hole is in unconsolidated glacial and alluvial materials. The remainder of the hole is in fine-grained quartzite. The quartzite is probably a part of the Guye Formation (Chitwood, 1976), and it was presumably metamorphosed during the intrusion of the Snoqualmie batholith which crops out a short distance to the northwest.

White River

The White River drill hole penetrated banded, devitrified pyroxene rhyolite which is the intrusive phase of the Clear West complex, a hypabyssal rhyolitic ignimbrite and extrusive rheoignimbrite (Fischer, 1970). The Clear West complex may represent a caldera filling or, in part, a very thick sill (Fischer, 1970). Hartman (1973) suggests that the complex may be a plug dome with associated sills. The rhyolites intrude the Eocene-Oligocene Ohanapecosh Formation and the early Miocene Fifes Peak Formation. Potassium-argon age dates indicate an age of 18 to 19 million years, or late early Miocene (Hartman, 1973).

Clear Creek

This drill hole intersected sandy siltstone and mudstone of the Russell Ranch Formation, a Jurassic flysch assemblage (Clayton, 1980). The Russell Ranch consists of tectonically deformed and broken argillite and feldspathic graywacke with lenses of greenstone, bedded chert, chert conglomerate, and metatuff (Ellingson, 1972; Swanson, 1978).

Sand Ridge

This drill hole penetrated a portion of the Indian Creek Amphibolite, a Jurassic complex emplaced as a solid mass within the Russell Ranch Formation. Composed of interlayered tectonic lenses of amphibolite, dioritic and tonalitic gneiss, hornblendite, and lesser amounts of quartz diorite pegmatite, cataclastic orthogneiss, and mylonite (Ellingson, 1968, 1972), the formation has been interpreted as part of an ophiolite assemblage (Hammond, 1980; Clayton, 1980, unpublished).

Tieton Willows

Two holes were drilled about 80 meters (m) apart at this site. The first hole was lost due to caving. It was collared in landslide materials, and encountered highly weathered and fractured volcanic conglomerates below. This hole was probably drilled into or through a steeply dipping or vertical fault or fracture zone.

The second hole, which was successfully completed, encountered competent lava flows at a depth of 10 m, and remained in them to its total depth. The lava flows are thought to be part of Tieton volcano, a Miocene shield volcano, which consists of andesite and basalt lava flows, breccia, and tuff (Swanson, 1966, 1978). Numerous andesitic radial dike swarms are also present. Swanson includes the Tieton volcano as part of the Fifes Peak Formation.

Trout Creek

This drill hole encountered 3 m of overburden, basalt from 3 to 8 m depth, highly variable incompetent materials from 8 to 25 m depth, and variably altered volcaniclastic rocks and flows of the Eocene-Oligocene Ohanapecosh Formation from 25 m to the bottom of the hole.

The basalt from 3 to 8 m depth is part of a Quaternary lava flow which originated at Trout Creek Hill, a small shield volcano centered about 4.5 kilometers northwest of the drill site (Wise, 1961, 1970). The flow is thought to be older than 35,000 years, but younger than 130,000 years (Hammond, 1980).

The unconsolidated material from 8 to 25 m depth probably represents valley-filling sediments of fluvial or glacial origin; some of the material is weathered bedrock.

Carson

The Carson drill hole was collared in the same Quaternary basalt flow as that encountered in the Trout Creek drill hole. At the Carson site the flow extends to a depth of 35 m. From 35 to 40 m depth a paleosol and glacial or fluvial sediments were encountered. Below this, to about 80 m, altered volcaniclastic rocks and thin lava flows of the Ohanapecosh Formation predominate, but chips of unaltered diorite appeared in several zones, perhaps representing thin dikes.

Below 80 m and extending to total depth at 154 m (the hole is completed to only 113.2 m because of caving), the rock is quartz diorite of the Buck Mountain intrusive (informal name), also informally known as the Wind River Gorge intrusive and Wind River fishway sill (Free, 1976). Free describes the rock as holocrystalline, augite-hypersthene diorite. If the intrusive correlates

with the similar rock of the Wind River plug, which intrudes Yakima basalt about 4 kilometers southeast of Buck Mountain, the Buck Mountain intrusive is middle Miocene in age, or younger.

Klickitat

The Klickitat drill hole is in Columbia River Basalt for its entire depth. From reconnaissance geologic mapping (Shannon and Wilson, Inc., 1973; Hammond, 1980) it appears that the basalt at the Klickitat drill hole is part of the Grande Ronde Basalt (early and middle Miocene), the most widespread member of the Yakima Basalt Subgroup.

Several zones of open fractures were encountered in the drill hole, most of which were lined with amorphous opaline silica. Open fracture zones were noted at depths near 10 m, 47 to 50 m, 62 m, 90 m, and 115 m. Carbon dioxide charged artesian water was produced from these zones during drilling, especially from the upper zones. The lower fracture zones may have been relatively underpressured because artesian flow ceased during the drilling of the lower part of the hole. All artesian zones were controlled by casing and(or) cementing during the process of completing the hole.

North Bonneville Nos. 1, 2, and 3

The following description of downhole lithologies was taken from an unpublished report to the City of North Bonneville (Kent and Associates, Consulting Geologists, 1981).

Alluvium and landslide debris extend down to about 40 m at NB-1, 48 m at NB-2, and 15 m at NB-3. Below this, conglomerates of the Eagle Creek Formation (early Miocene) extend to depths of about 125 m in NB-1, 115 m in NB-2, and 70 m in NB-3. The conglomerates are predominantly fluvial volcaniclastics.

The lower portions of all three holes, beneath the Eagle Creek Formation, consist of variably altered tuffs and flows. The consultant's report interprets the unit to be part of the Three Corner Rock lava flows, which are estimated to be late Oligocene to early Miocene in age. Hammond (1980) describes the Three Corner Rock lava flows as interstratified pyroxene andesite porphyry, hornblende-pyroxene andesite porphyry, laharic breccia, and minor volcaniclastic rocks.

Because of the extensive alteration reported for cuttings from the lower portions of the North Bonneville holes, we believe it possible that the lower parts of the three drill holes may have penetrated into the Ohanapecosh Formation instead of the Three Corner Rock lava flows.

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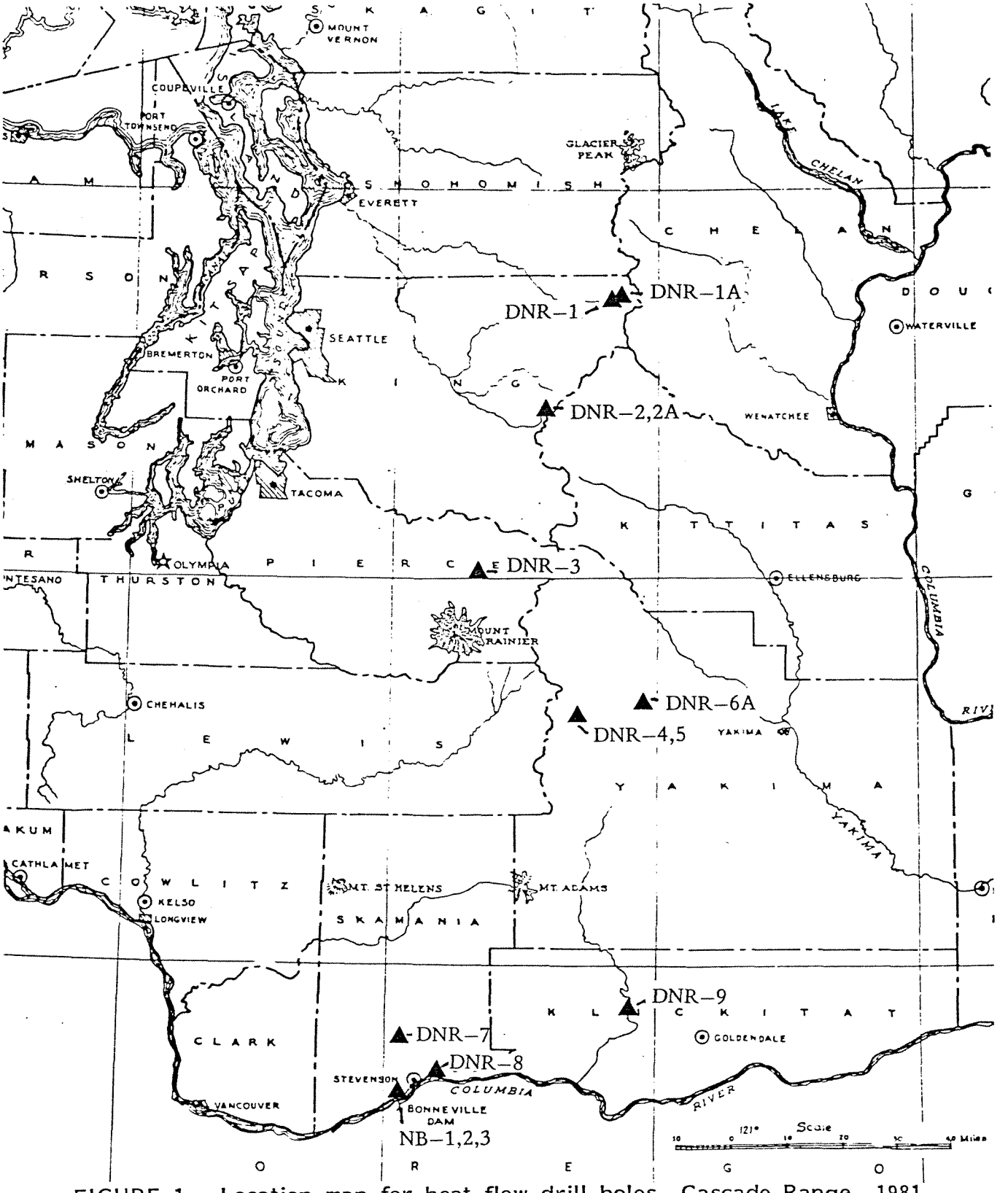

FIGURE 1.—Location map for heat-flow drill holes, Cascade Range, 1981. (Drill holes: DNR-1, Scenic No. 1; DNR-1A, Scenic No. 2; DNR-2, Snoqualmie No. 1; DNR-2A, Snoqualmie No. 2; DNR-3, White River; DNR-4. Clear Creek; DNR-5, Sand Ridge; DNR-6A, Tieton Willows; DNR-7, Trout Creek; DNR-8, Carson; DNR-9, Klickitat; NB-1, North Bonneville No. 1; NB-2, North Bonneville No. 2; and NB-3, North Bonneville No. 3.)

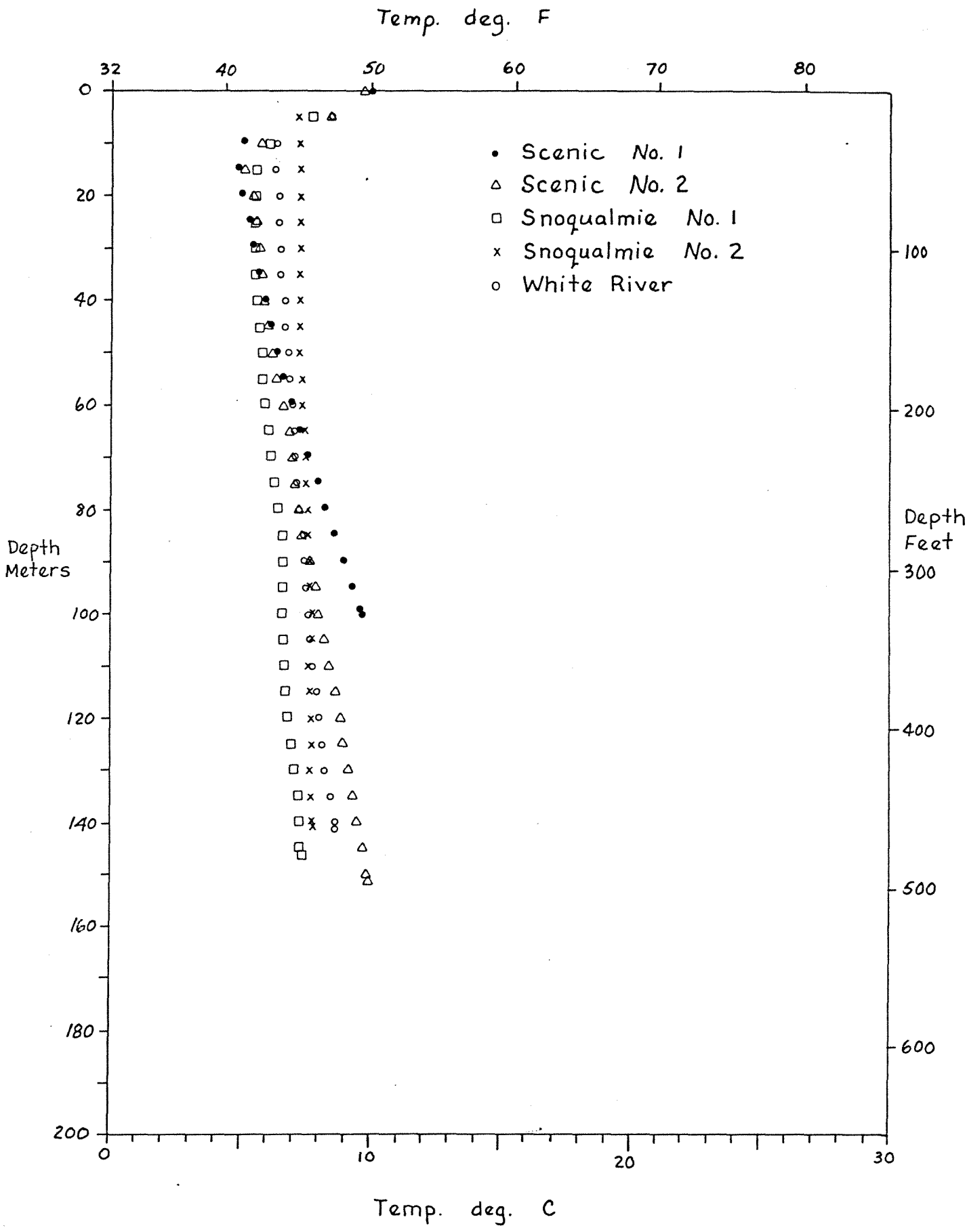

FIGURE 2.—Composite temperature-depth plots for Scenic No. 1 (DNR-1), Scenic No. 2 (DNR-1A), Snoqualmie No. 1 (DNR-2), Snoqualmie No. 2 (DNR-2A), and White River (DNR-3) drill holes.

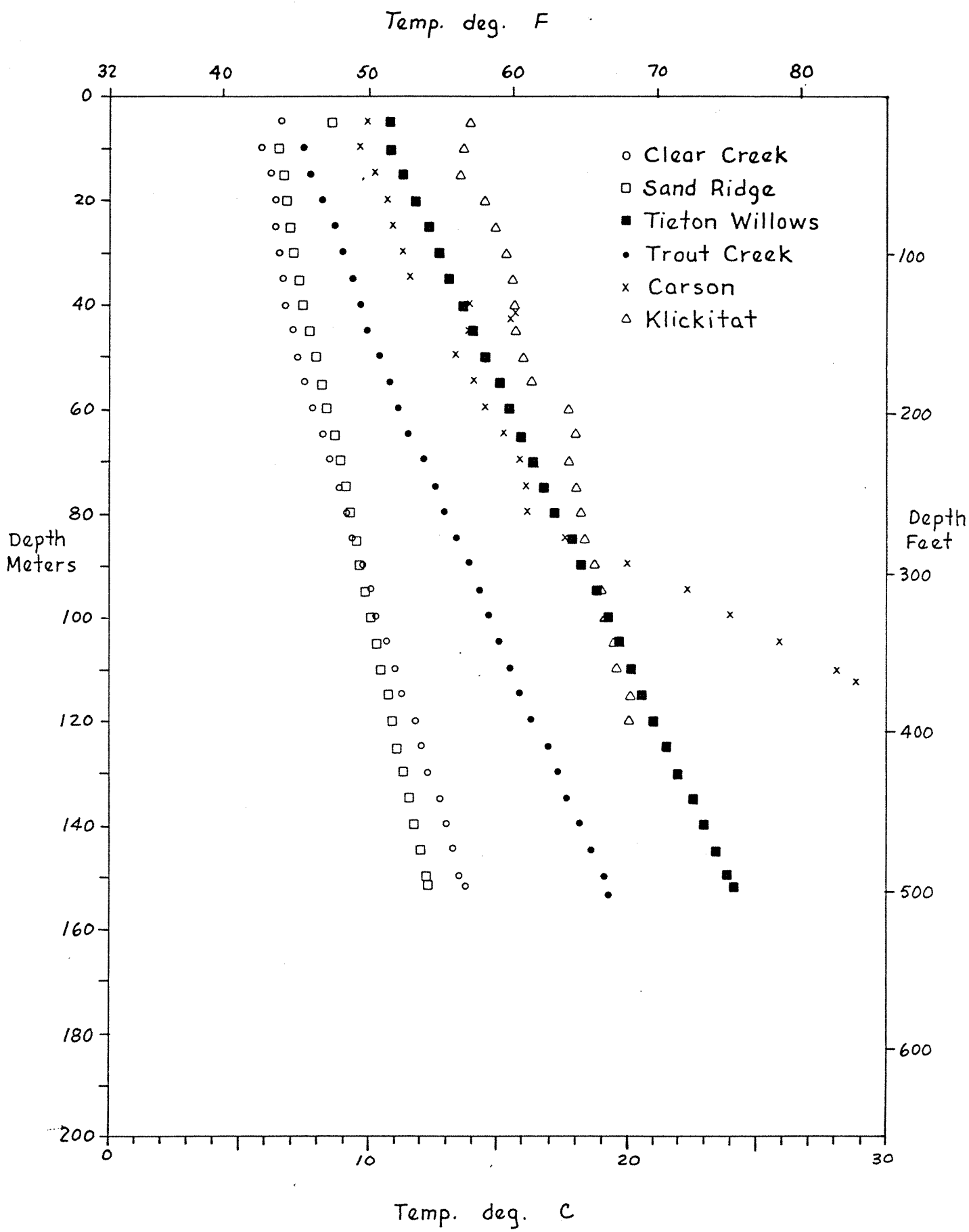

FIGURE 3.—Composite temperature-depth plots for Clear Creek (DNR-4), Sand Ridge (DNR-5), Tieton Willows (DNR-6A), Trout Creek (DNR-7), Carson (DNR-8), and Klickitat (DNR-9) drill holes.

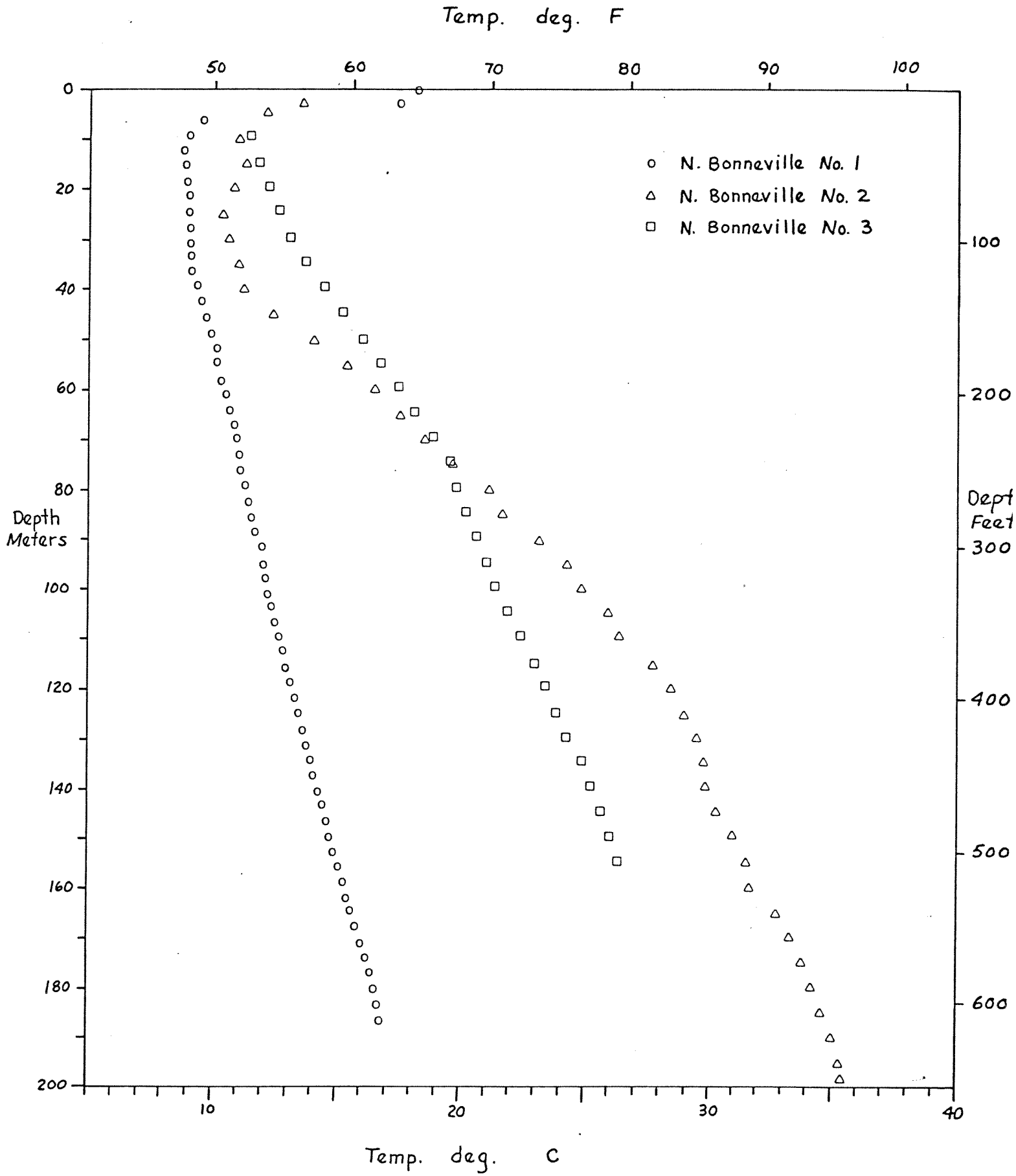

FIGURE 4.—Composite temperature-depth plots for North Bonneville No. 1 (NB-1), North Bonneville No. 2 (NB-2), and North Bonneville No. 3 (NB-3) drill holes.

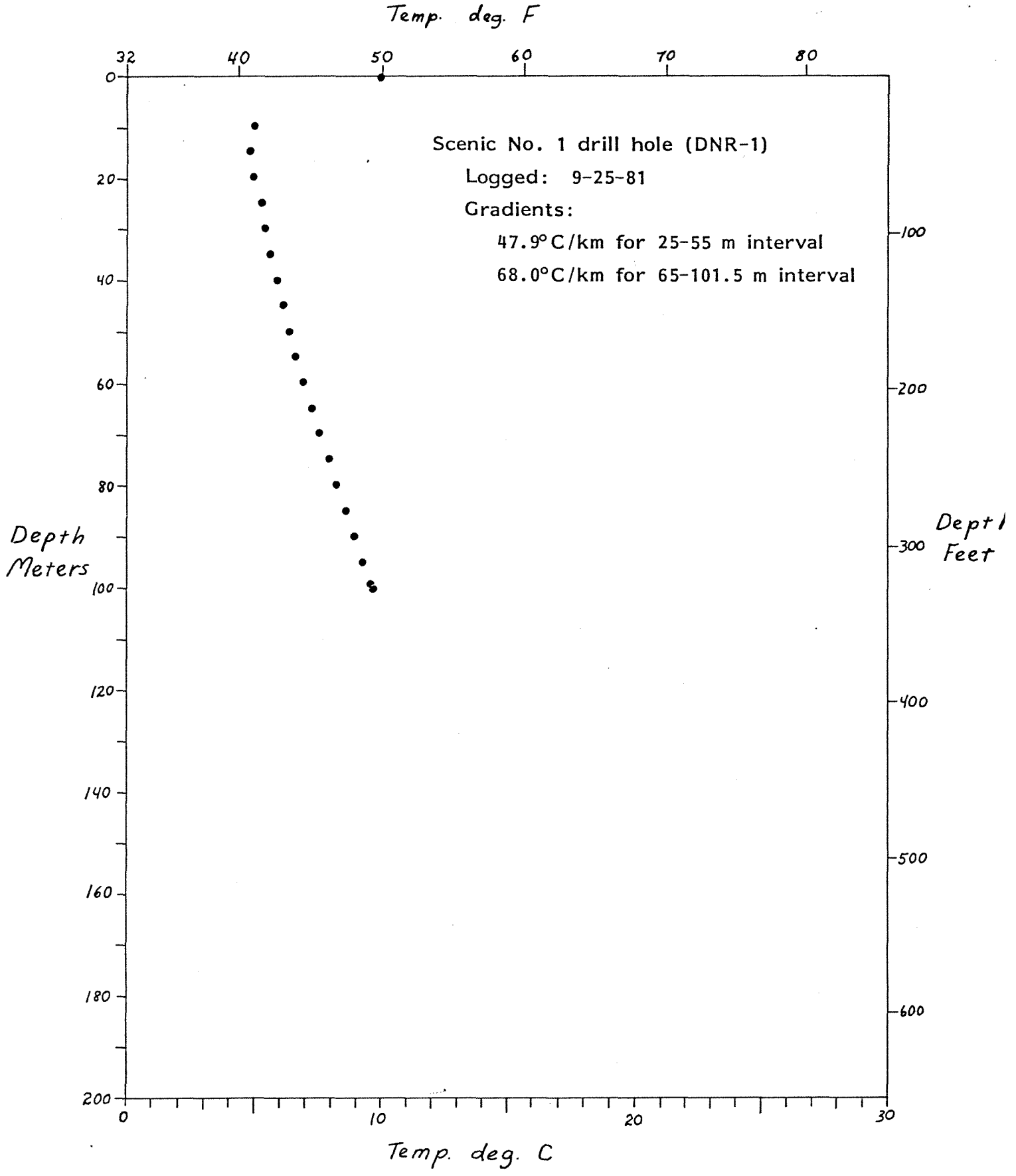

FIGURE 5.—Temperature-depth plot for Scenic No. 1 (DNR-1) drill hole.

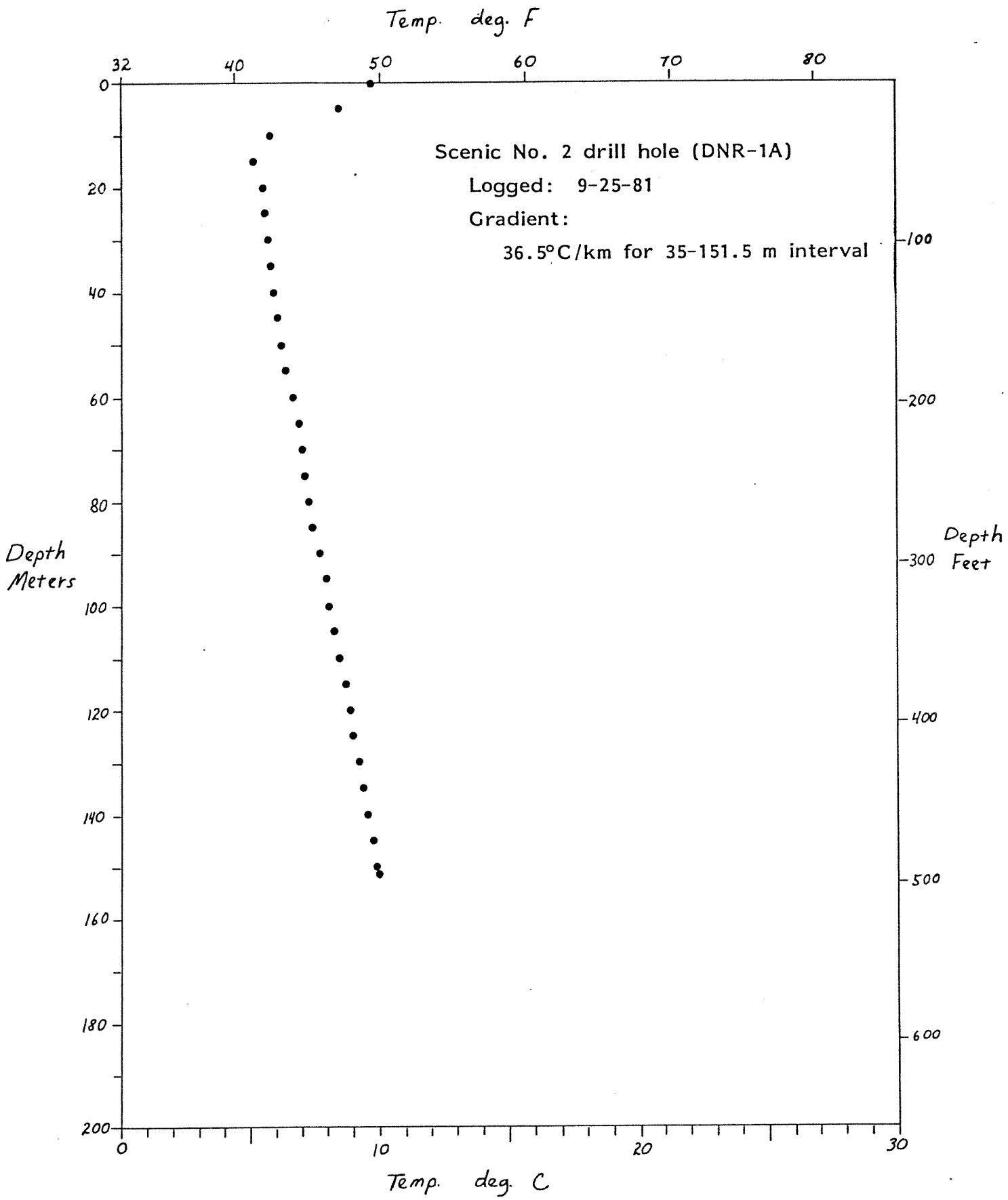

FIGURE 6.—Temperature-depth plot for Scenic No. 2 (DNR-1A) drill hole.

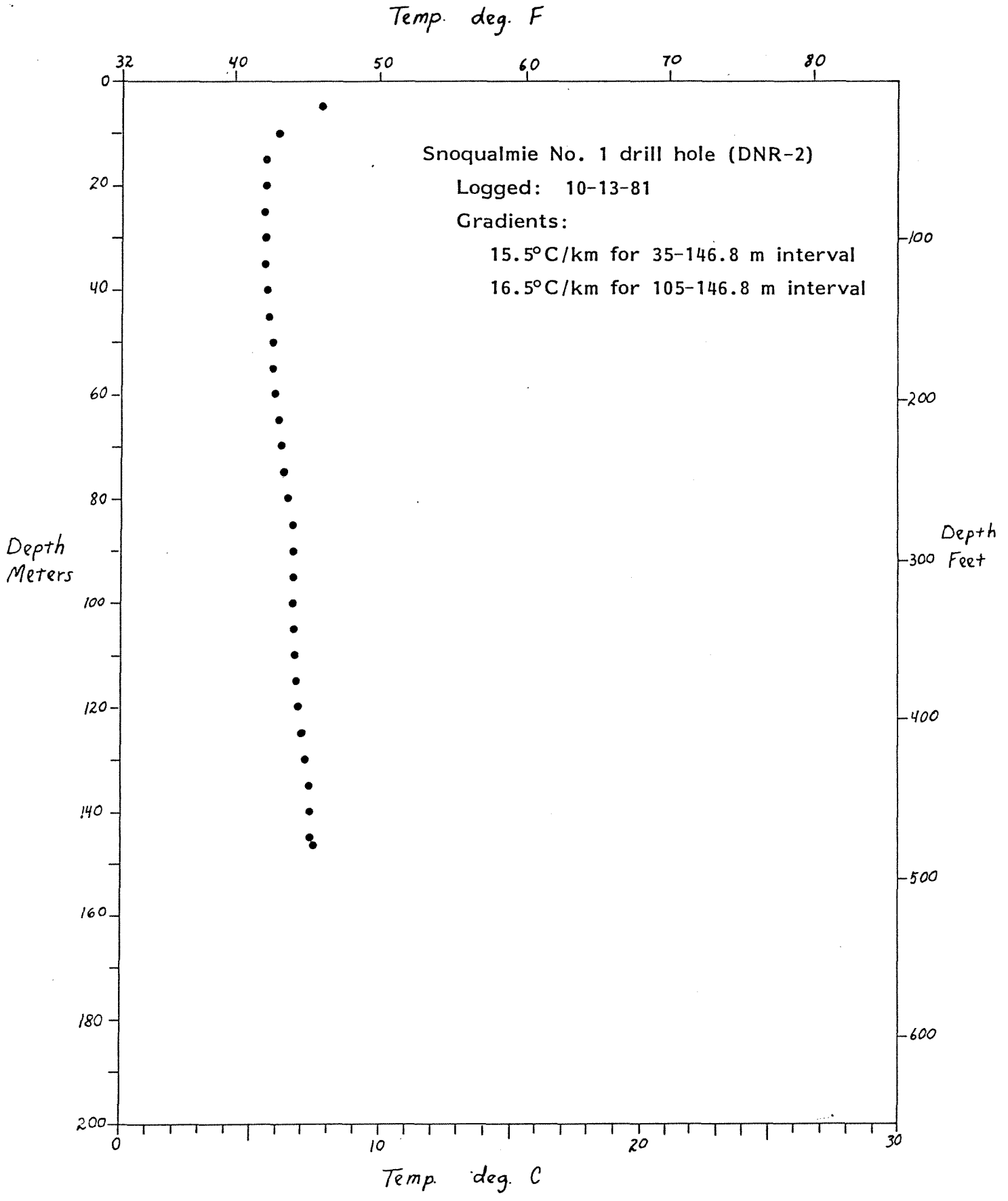

FIGURE 7.—Temperature-depth plot for Snoqualmie No. 1 (DNR-2) drill hole.

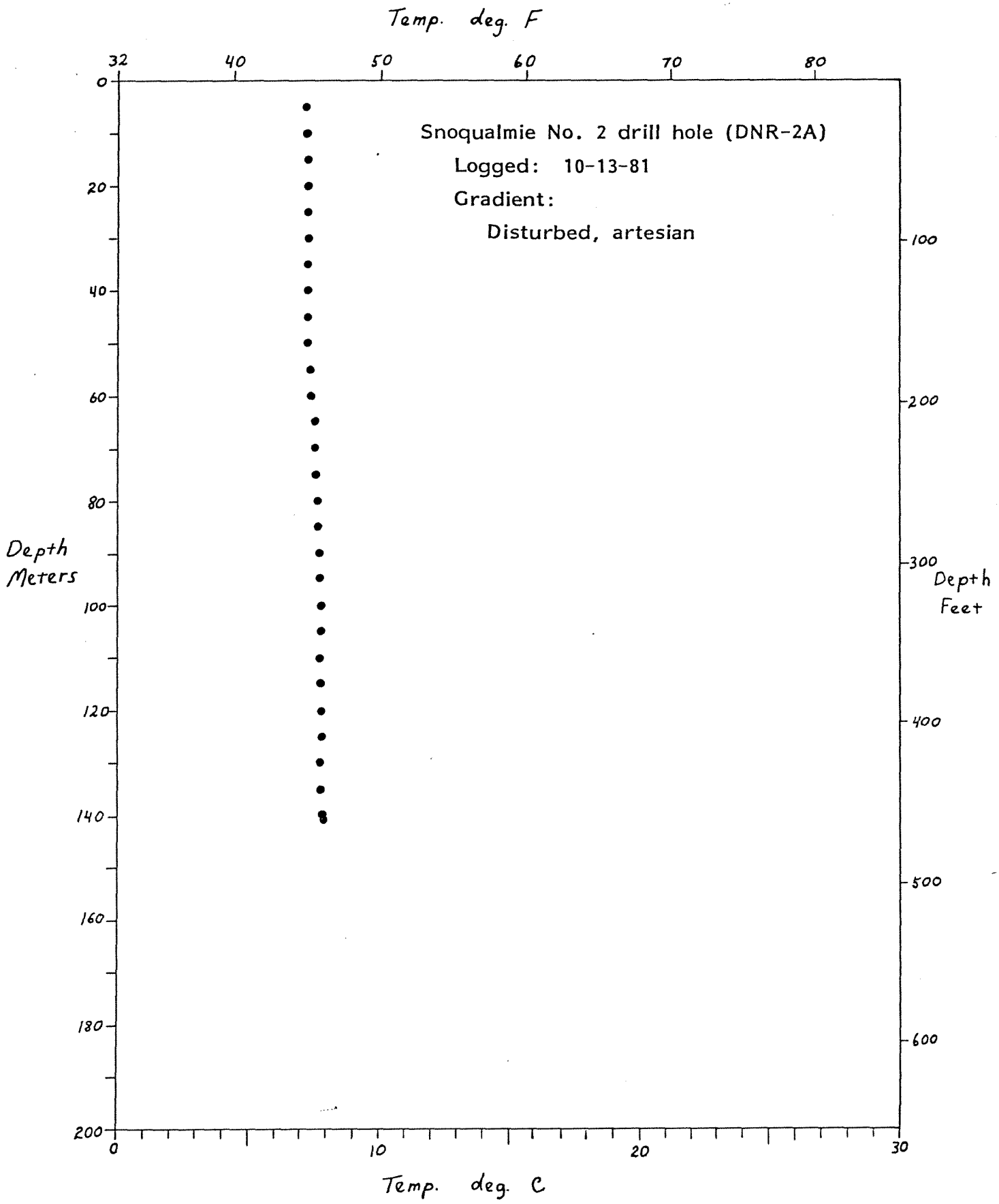

FIGURE 8.—Temperature-depth plot for Snoqualmie No. 2 (DNR-2A) drill hole.

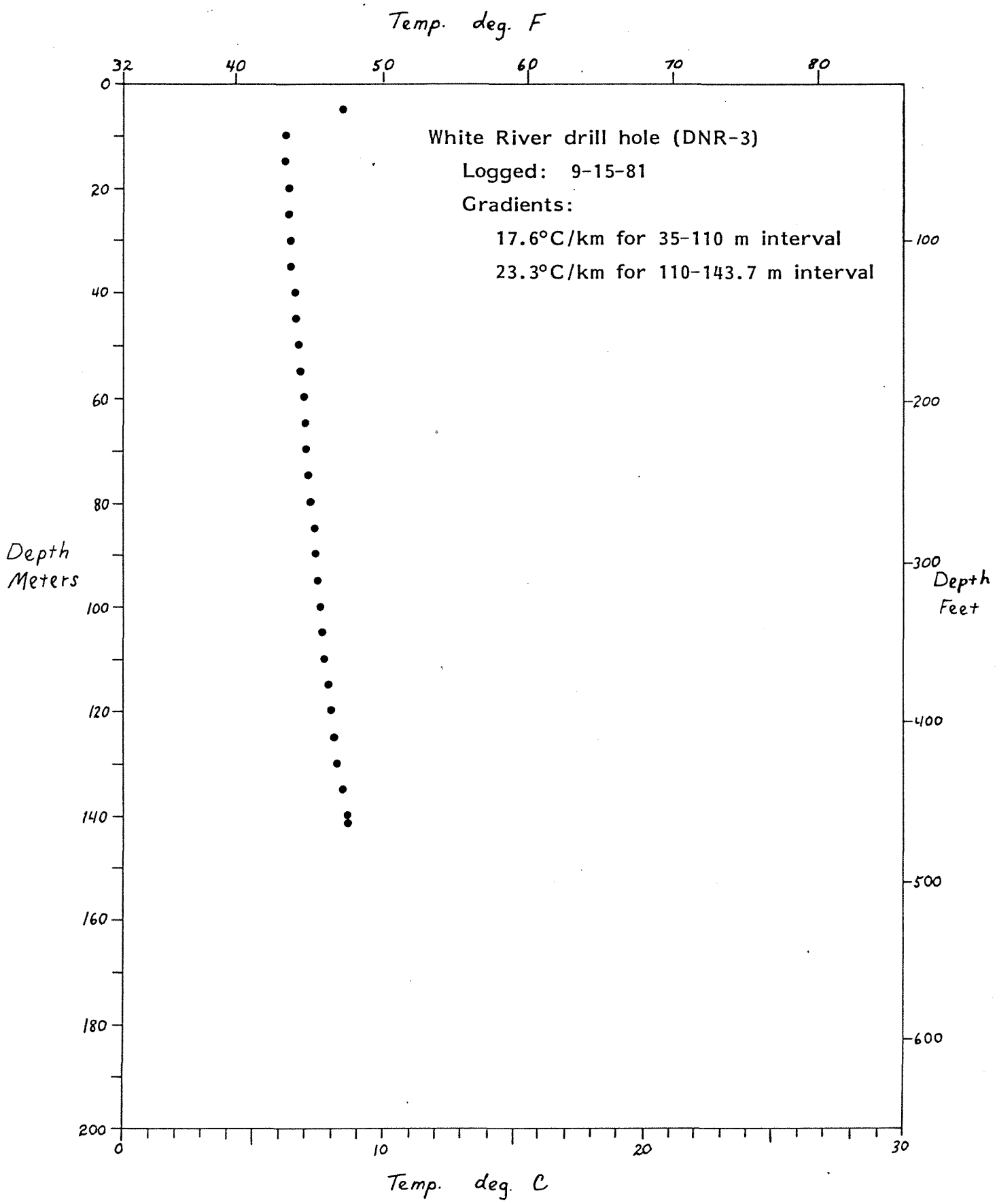

FIGURE 9.—Temperature-depth plot for White River (DNR-3) drill hole.

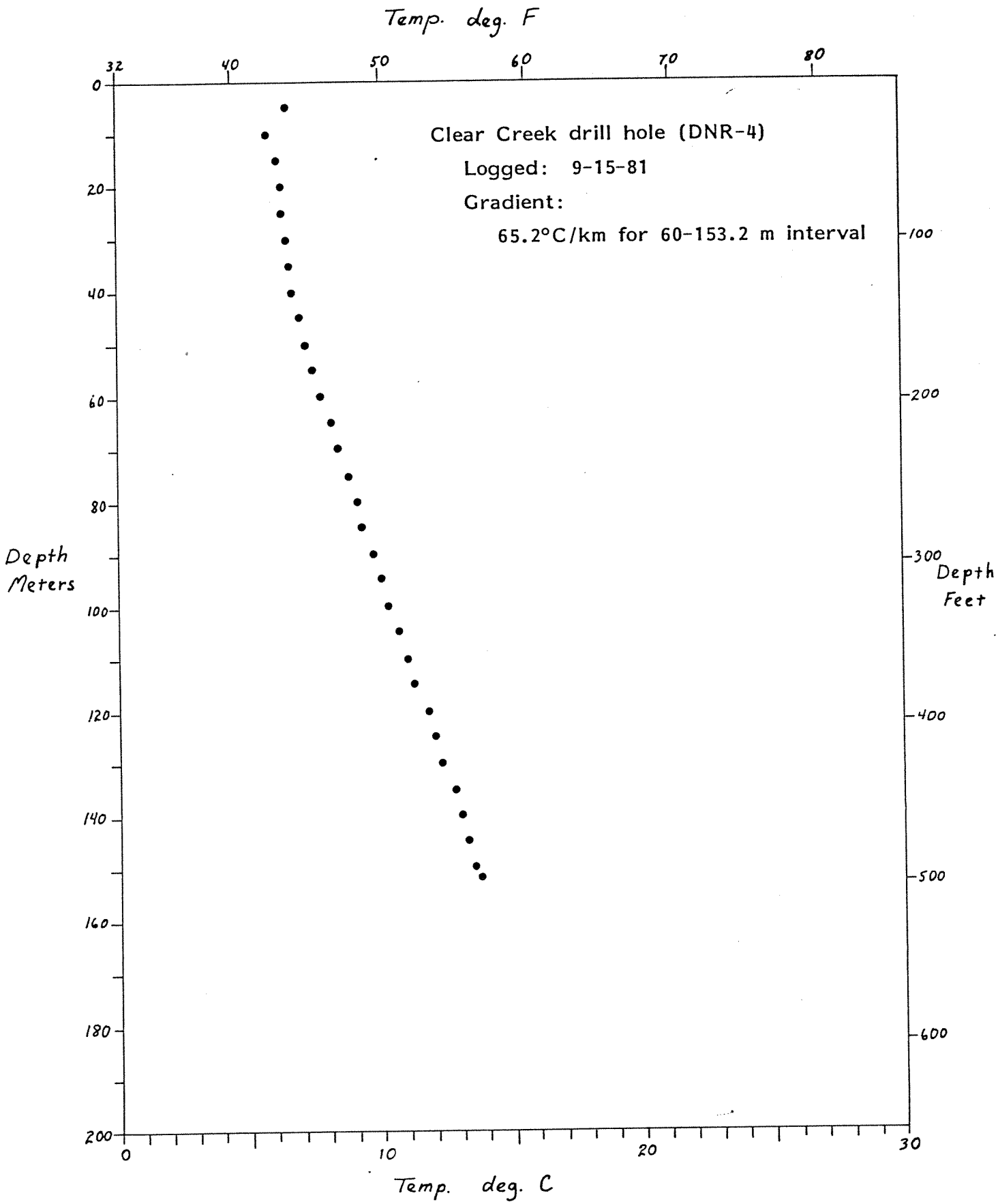

FIGURE 10.—Temperature-depth plot for Clear Creek (DNR-4) drill hole.

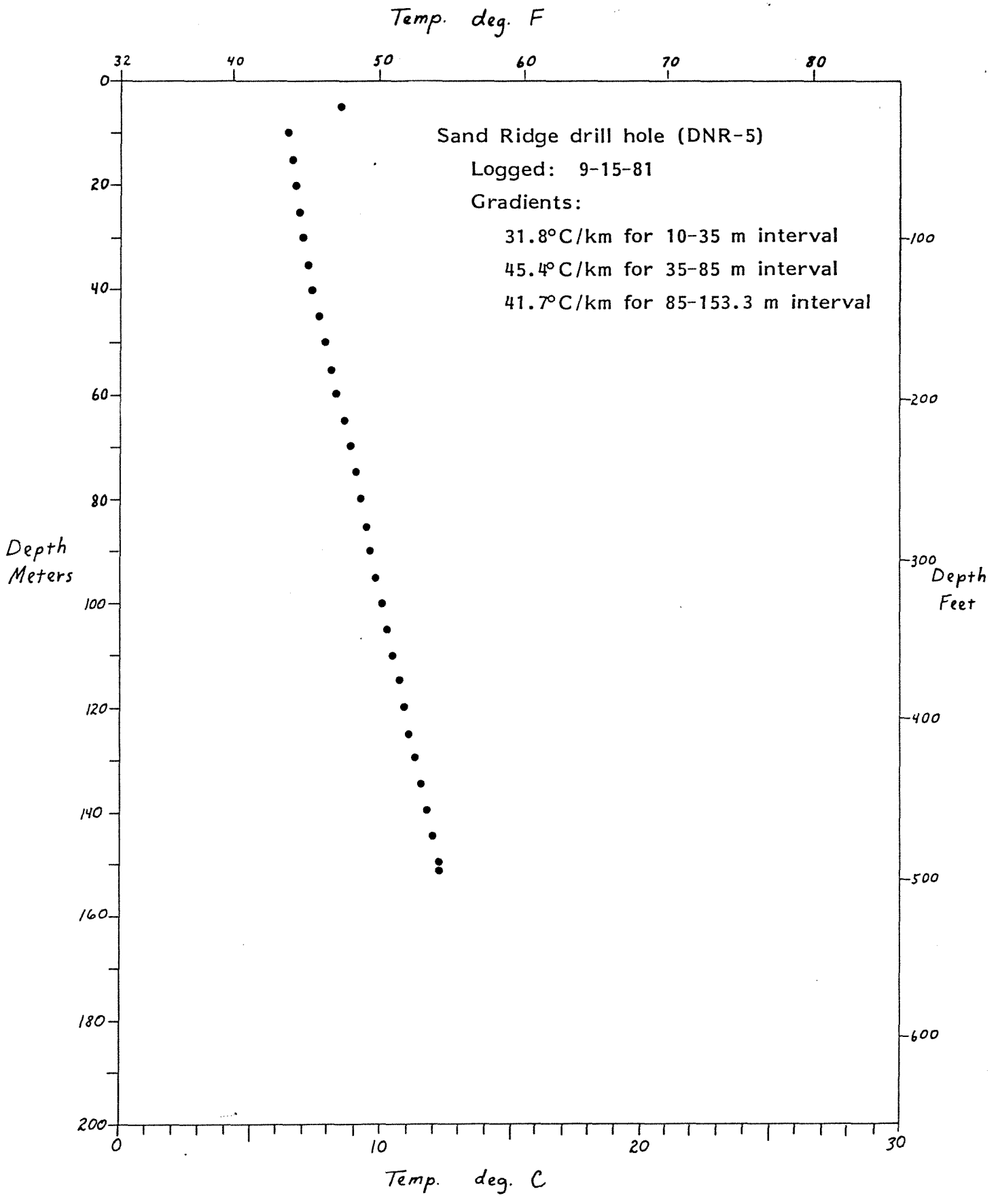

FIGURE 11.—Temperature-depth plot for Sand Ridge (DNR-5) drill hole.

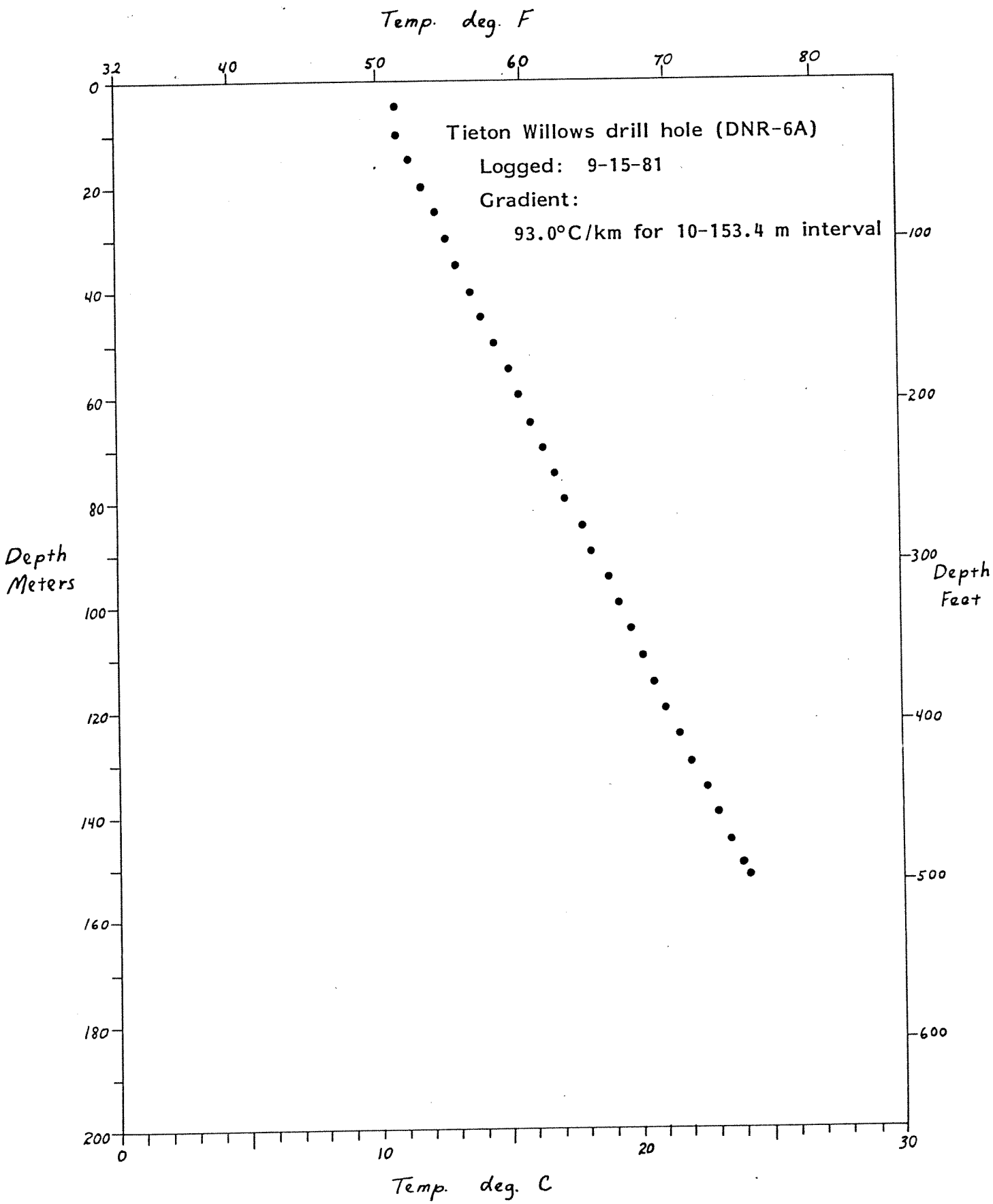

FIGURE 12.—Temperature-depth plot for Tieton Willows (DNR-6A) drill hole.

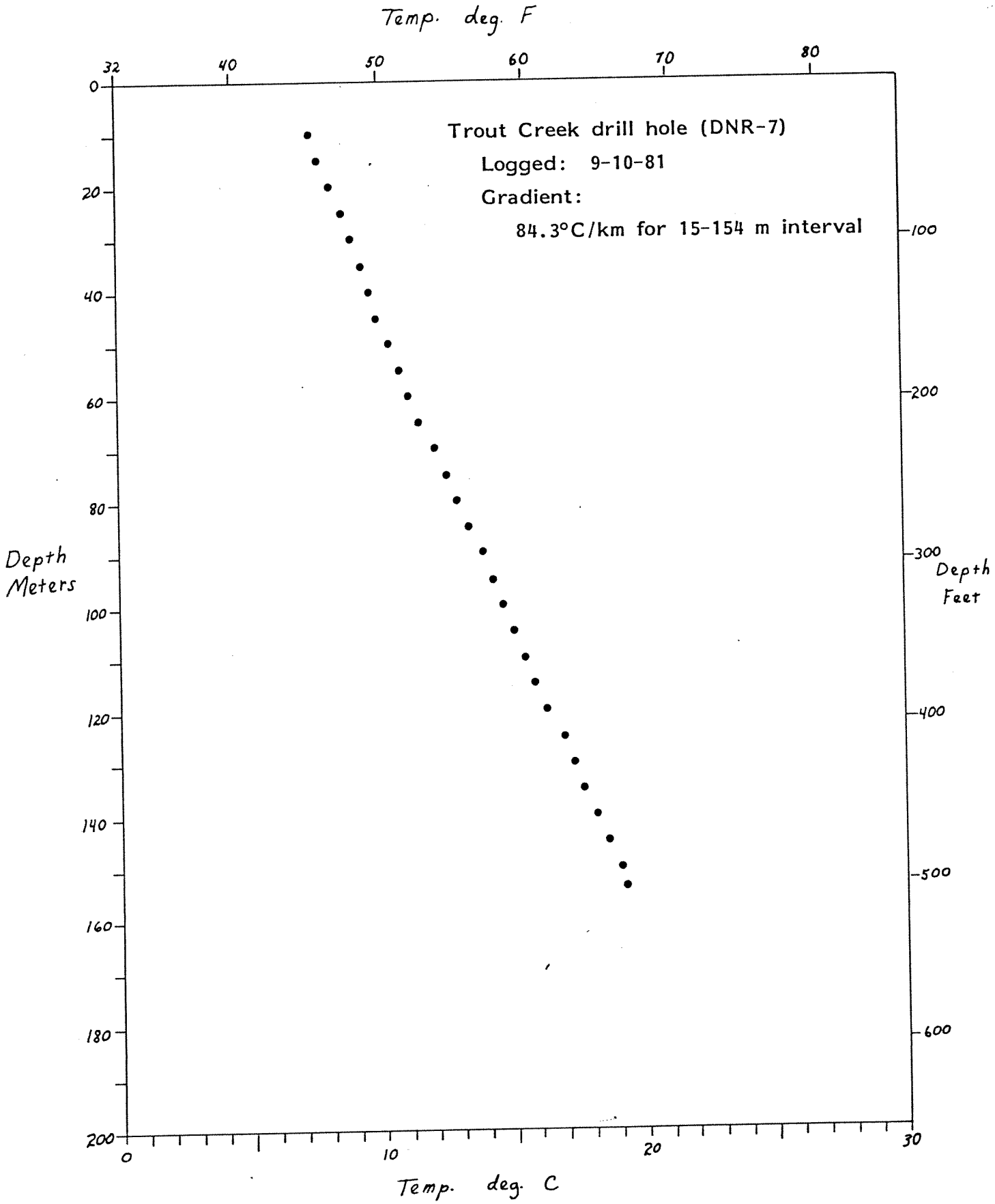

FIGURE 13.—Temperature-depth plot for Trout Creek (DNR-7) drill hole.

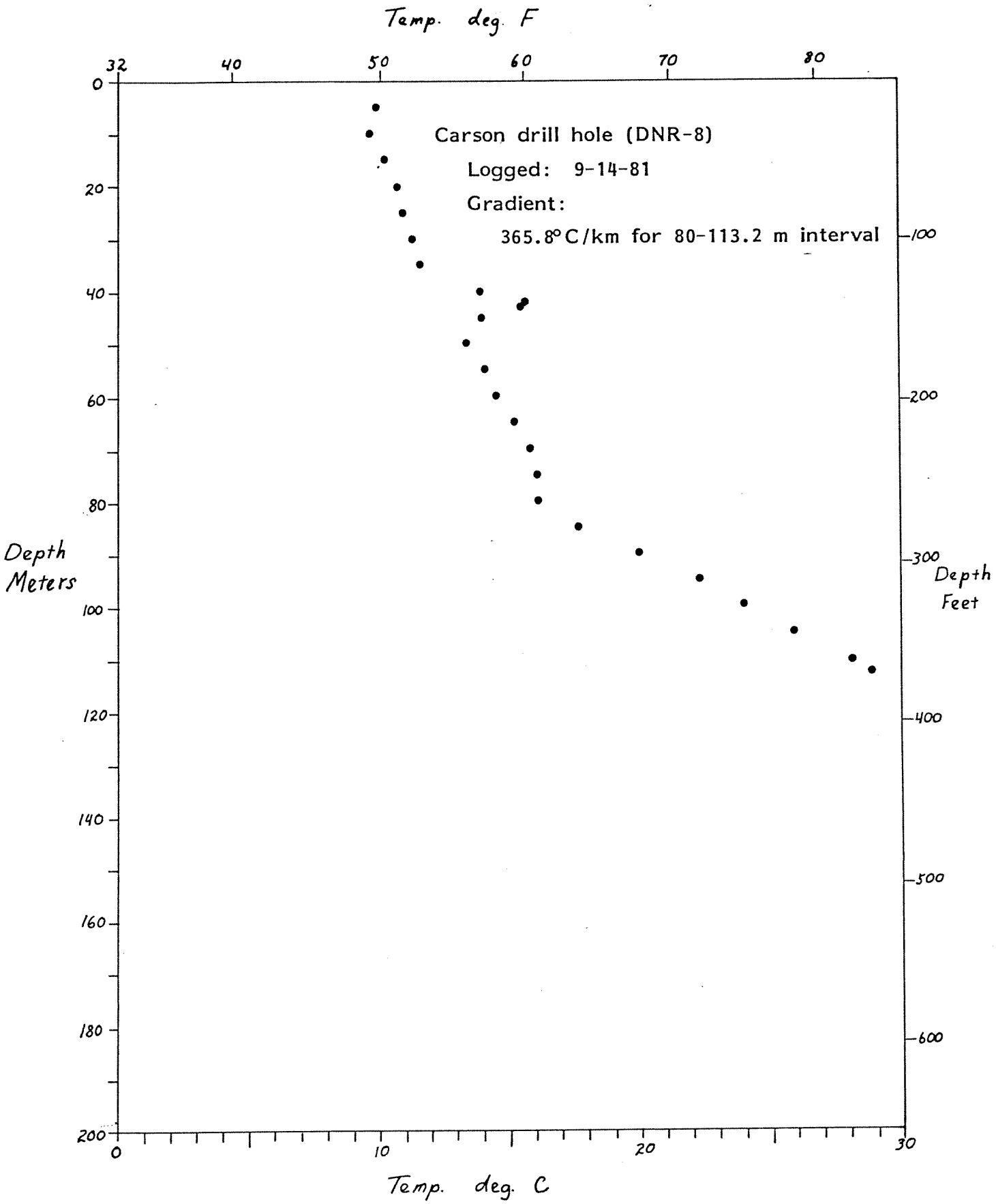

FIGURE 14.—Temperature-depth plot for Carson (DNR-8) drill hole.

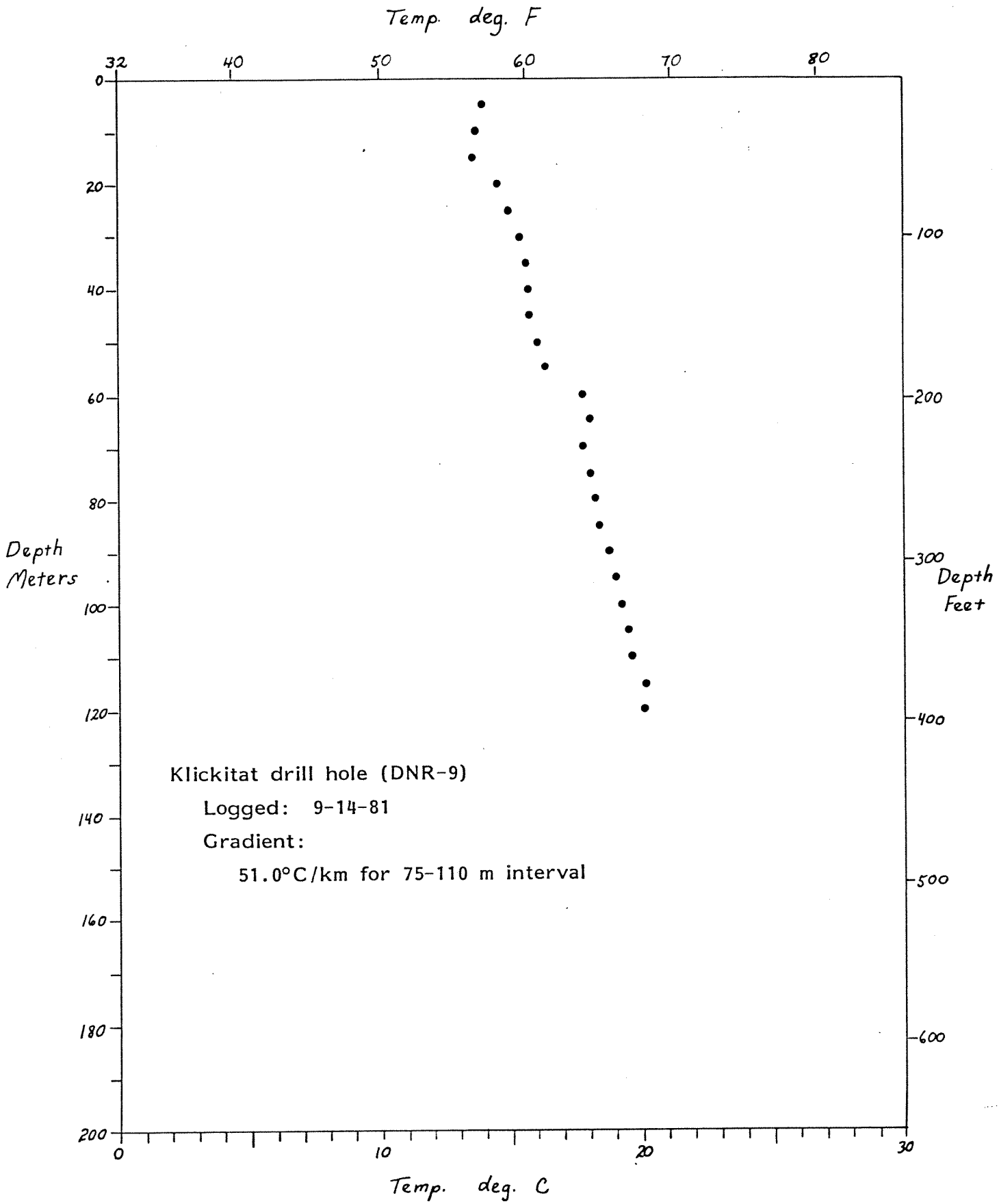

FIGURE 15.—Temperature-depth plot for Klickitat (DNR-9) drill hole.

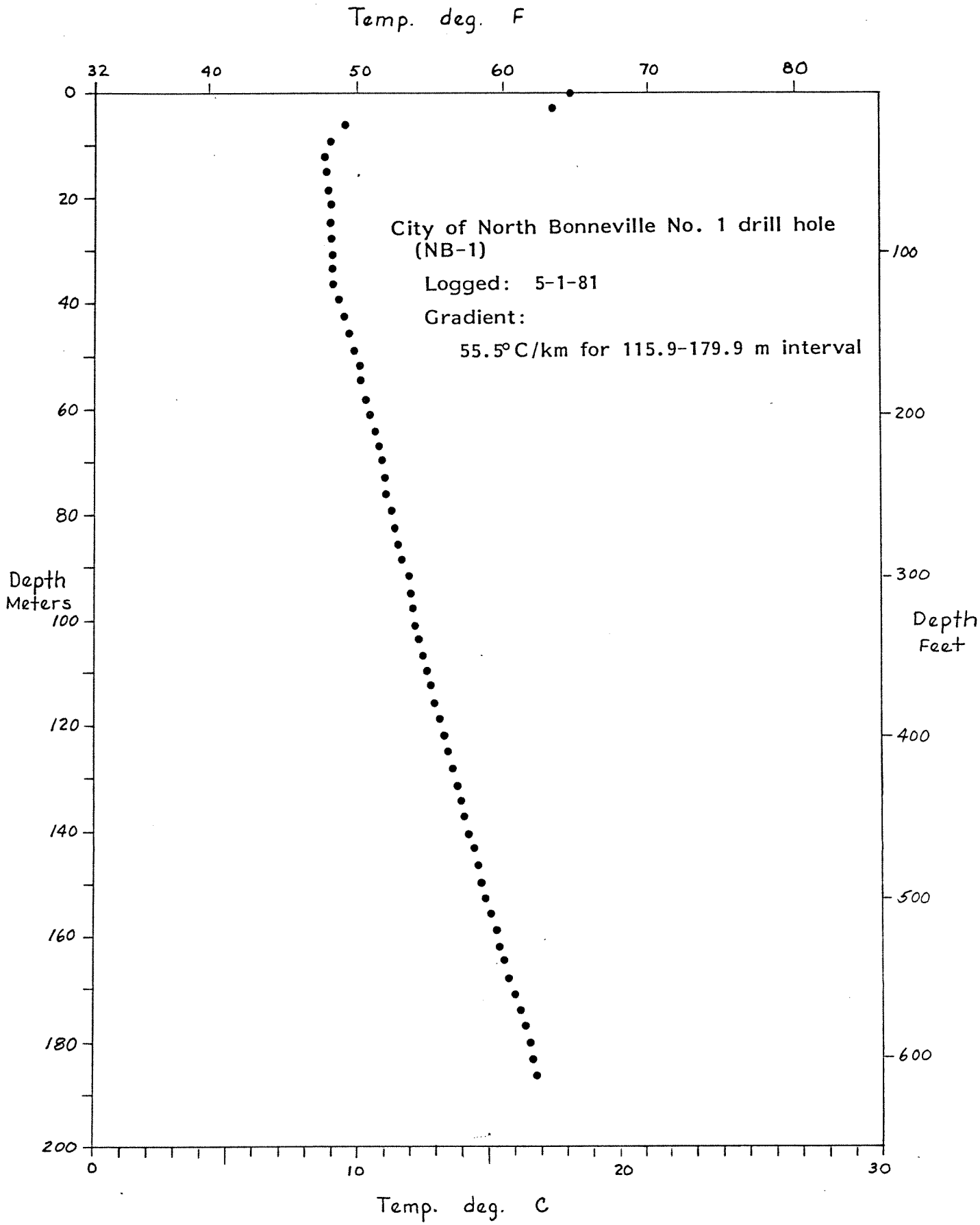

FIGURE 16.—Temperature-depth plot for North Bonneville No. 1 (NB-1) drill hole.

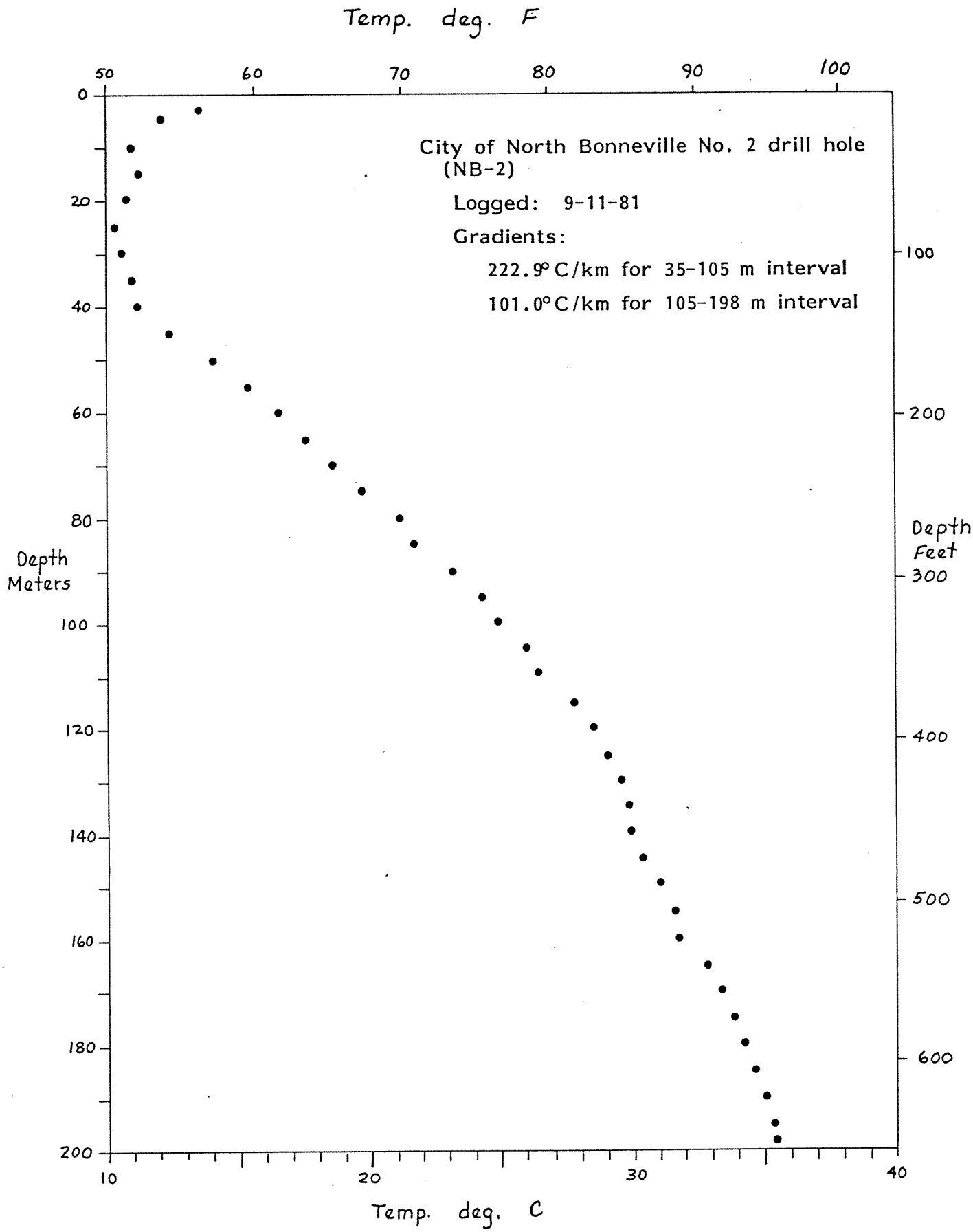

FIGURE 17.—Temperature-depth plot for North Bonneville No. 2 (NB-2) drill hole.

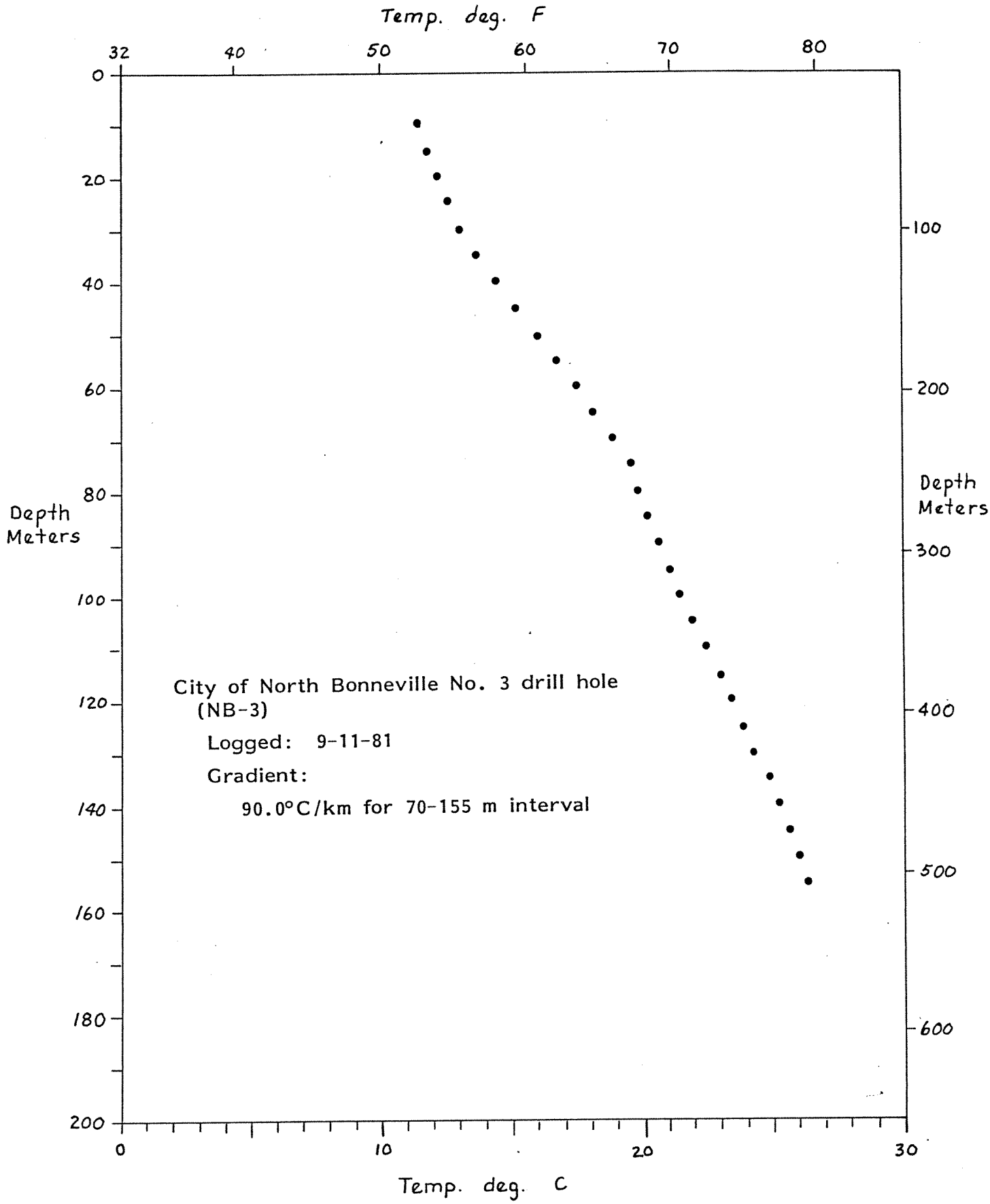

FIGURE 18.—Temperature-depth plot for North Bonneville No. 3 (NB-3) drill hole.

TABLE 1.—*Cascade Range temperature gradients from 1981 drilling*

Drill hole		County	Location			Elev. topo. (m)	Spud completion dates (1981)	Date logged (1981)	T.D. (m)	B.H.T. °C	Est. surface temp. °C	Gradient "A"[1/]		Gradient "B"[3/] °C/km	USGS topo. quad.
No.	Name			North latitude	West longitude							Depth interval (m)	°C/km ($S_{\hat{\beta}_1}$)[2/]		
DNR-1	Scenic No. 1	King	SE¼SW¼ sec. 28 (26-13E)	47°42'39.3"	121°08'30.0"	841	6/23-25	9/25	101.5	9.77	4.7	25-55 65-101.5	47.9 (0.8) 68.0 (0.2)	50	Scenic 7.5'
DNR-1A	Scenic No. 2	King	NE¼NW¼ sec. 27 (26-13E)	47°43'12.0"	121°07'12.7"	841	6/26-29	9/25	151.5	9.97	5.0	35-151.5	36.5 (0.1)	36.5	Stevens Pass 7.5
DNR-2	Snoqualmie No. 1	King	NE¼SE¼NW¼ sec. 4 (22-11E)	47°25'32.4"	121°24'48.0"	908	6/30-7/3	10/13	146.8	7.38	5.6	35-146.8 105-146.8	15.5 (0.2) 16.5 (0.1)	12.1	Snoqualmie Pass 15'
DNR-2A	Snoqualmie No. 2 (D. Dyer well)	King	NW¼NE¼SW¼ sec. 33 (23-11E)	47°26'10.9"	121°24'55.5"	899	7/6-10	10/13	141	7.86	5.6	Disturbed artesian		16.0	Snoqualmie Pass 15'
DNR-3	White River	Pierce	NW¼SW¼ sec. 29 (18-9E)	47°00'32.4"	121°41'42.5"	853	7/13-16	9/15	143.7	8.64	6.0	35-110 110-143.7	17.6 (0.1) 23.3 (0.5)	18	Greenwater 15'
DNR-4	Clear Creek	Yakima	NW¼NW¼ sec. 3 (13-12E)	46°39'09.0"	121°19'49.7"	1006	7/17-22	9/15	153.2	13.78	5.0	60-153.2	65.2 (0.2)	57	White Pass 15'
DNR-5	Sand Ridge	Yakima	NW¼NE¼ sec. 2 (13-12E)	46°38'58.8"	121°17'01.2"	1061	7/22-24	9/15	153.3	12.36	6.5	10-35 35-85 85-153.3	31.8 (1.0) 45.4 (0.3) 41.7 (0.2)	38	White Pass 15'
DNR-6A	Tieton Willows	Yakima	SW¼NW¼ sec. 25 (14-14E)	46°40'26.2"	121°01'42.3"	744	7/27-31	9/15	153.4	24.14	10.5	10-153.4	93.0 (0.3)	89	Tieton Basin 7.5'
DNR-7	Trout Creek	Skamania	SE¼SW¼ sec. 21 (4-7E)	45°48'36.9"	121°57'11.1"	366	8/5-7	9/10	154	19.23	7.0	15-154	84.3 (0.5)	79	Wind River 15'
DNR-8	Carson	Skamania	SE¼SE¼NW¼ sec. 21 (3-8E)	45°44'04.3"	121°48'14.4"	137	8/7-11	9/14	113.2	27.80	9.0	80-113.2	365.8 (14.3)	166	Carson 7.5'
DNR-9	Klickitat	Klickitat	SW¼NW¼ sec. 24 (4-13E)	45°49'24.2"	121°07'43.1"	146	8/18-21	9/14	119.8	20.06	13.5	75-110	51.0 (0.6)	56	Klickitat 15'
NB-1	City of North Bonneville No. 1	Skamania	Sec. 40 (2-7E)	45°38'24.5"	121°58'32.2"	14	4/16-21	5/1	186	16.67	8.0	115.9-179.9	55.5 (0.3)	47	Bonneville Dam 7.5'
NB-2	City of North Bonneville No. 2	Skamania	Sec. 39 (2-7E)	45°38'54.9"	121°57'14.4"	14	4/22-30	9/11	198	35.45	10.5	35-105 105-198	222.9 (3.8) 101.0 (2.7)	126	Bonneville Dam 7.5'
NB-3	City of North Bonneville No. 3	Skamania	Sec. 39 (2-7E)	45°39'09.0"	121°57'36.7"	15	5/11-22	9/11	155	26.38	11.0	70-155	90.0 (0.9)	99	Bonneville Dam 7.5'

1/ Gradient "A"—Slope of A least-squares straight line fitted to the temperature-depth data for the depth interval indicated.

2/ $S_{\hat{\beta}_1}$ — Standard deviation, expressed

as $$S_{\hat{\beta}_1} = \frac{\sum y_i^2 - n\bar{y}^2 - \hat{\beta}_1\left(\sum x_i y_i - n\bar{x}\bar{y}\right)}{\left(\sum x_i^2 - n\bar{x}^2\right)(n-2)}$$

where $S_{\hat{\beta}_1}$ = standard deviation of the slope of the regression line

y_i = a temperature reading where $i = 1-n$.

x_i = the depth where y_i was read

n = number of temperature-depth readings.

$\hat{\beta}_1$ = the estimated slope (temperature gradient)

$\bar{X}$ = mean of depth readings, and

$\bar{Y}$ = mean of temperature readings

3/ Gradient "B"—Temperature gradient calculated using an estimated surface or near-surface temperature and a measured bottom hole temperature. Useful especially when straight-line conductive gradients are not present in a hole because of hydrologic disturbances.

TABLE 2.—Geothermal temperature gradient measurements for Scenic No. 1 drill hole, DNR-1 (date measured 9-25-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
10	5.08	-42
15	4.87	24
20	4.99	58
25	5.28	42
30	5.49	44
35	5.71	48
40	5.95	50
45	6.20	50
50	6.45	52
55	6.71	58
60	7.00	60
65	7.30	64
70	7.62	68
75	7.96	68
80	8.30	68
85	8.64	68
90	8.98	70
95	9.33	68
100	9.67	67
101.5 T.D.	9.77	

TABLE 3.—Geothermal temperature gradient measurements for Scenic No. 2 drill hole, DNR-1A (date measured 9-25-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
5	8.34	-536
10	5.66	-112
15	5.10	60
20	5.40	4
25	5.42	22
30	5.53	36
35	5.71	30
40	5.86	38
45	6.05	36
50	6.23	34
55	6.40	46
60	6.63	40
65	6.83	26
70	6.96	34
75	7.13	34
80	7.30	34
85	7.47	38
90	7.66	36
95	7.84	40
100	8.04	36
105	8.22	36
110	8.40	36
115	8.58	34
120	8.75	40
125	8.95	38
130	9.14	38
135	9.33	40
140	9.53	38
145	9.72	38
150	9.91	40
151.5 T.D.	9.97	

TABLE 4.—Geothermal temperature gradient measurements for Snoqualmie No. 1 drill hole, DNR-2 (date measured 10-13-81)

Depth (m)	Temperature °C/km	Geothermal gradient °C/km
5	7.88	
10	6.19	-338
15	5.63	-112
20	5.63	0
25	5.63	0
30	5.64	2
35	5.64	0
40	5.72	16
45	5.81	18
50	5.87	12
55	5.93	12
60	6.03	20
65	6.08	10
70	6.12	8
75	6.21	18
80	6.31	20
85	6.43	24
90	6.59	32
95	6.69	20
100	6.68	-2
105	6.70	4
110	6.77	14
115	6.85	16
120	6.93	16
125	7.01	16
130	7.10	18
135	7.18	16
140	7.27	18
145	7.35	16
146.8 T.D.	7.38	17

TABLE 5.—Geothermal temperature gradient measurements for Snoqualmie No. 2 drill hole, DNR-2A (date measured 10-13-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
5	7.23	
10	7.22	-2
15	7.20	-4
20	7.22	4
25	7.22	0
30	7.22	0
35	7.23	2
40	7.23	0
45	7.24	2
50	7.21	-6
55	7.33	24
60	7.38	10
65	7.49	22
70	7.49	0
75	7.51	4
80	7.58	14
85	7.58	0
90	7.66	16
95	7.66	0
100	7.67	2
105	7.67	0
110	7.68	2
115	7.63	-10
120	7.75	24
125	7.76	2
130	7.82	12
135	7.83	2
140	7.85	4
141 T.D.	7.86	10

TABLE 6.—Geothermal temperature gradient measurements for White River drill hole, DNR-3 (date measured 9-15-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
5	8.48	
		-418
10	6.39	
		-14
15	6.32	
		22
20	6.43	
		4
25	6.45	
		14
30	6.52	
		8
35	6.56	
		16
40	6.64	
		14
45	6.71	
		16
50	6.79	
		20
55	6.89	
		16
60	6.97	
		16
65	7.05	
		18
70	7.14	
		18
75	7.23	
		18
80	7.32	
		18
85	7.41	
		18
90	7.50	
		18
95	7.59	
		20
100	7.69	
		18
105	7.78	
		20
110	7.88	
		22
115	7.99	
		24
120	8.11	
		28
125	8.25	
		20
130	8.35	
		24
135	8.47	
		26
140	8.60	
		11
143.7 T.D.	8.64	

TABLE 7.—Geothermal temperature gradient measurements for Clear Creek drill hole, DNR-4 (date measured 9-15-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
5	6.51	
		-140
10	5.81	
		58
15	6.10	
		40
20	6.30	
		16
25	6.38	
		12
30	6.44	
		8
35	6.48	
		54
40	6.75	
		48
45	6.99	
		52
50	7.25	
		54
55	7.52	
		52
60	7.78	
		62
65	8.09	
		60
70	8.39	
		64
75	8.71	
		70
80	9.06	
		66
85	9.39	
		62
90	9.70	
		60
95	10.00	
		66
100	10.33	
		64
105	10.65	
		74
110	11.02	
		66
115	11.35	
		66
120	11.68	
		66
125	12.01	
		62
130	12.32	
		66
135	12.65	
		62
140	12.96	
		76
145	13.34	
		54
150	13.61	
		53
153.2 T.D.	13.78	

TABLE 8.—Geothermal temperature gradient measurements for Sand Ridge drill hole, DNR-5 (date measured 9-15-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
5	8.49	
		-398
10	6.50	
		22
15	6.61	
		36
20	6.79	
		30
25	6.94	
		32
30	7.10	
		38
35	7.29	
		40
40	7.49	
		40
45	7.69	
		50
50	7.94	
		46
55	8.17	
		44
60	8.39	
		46
65	8.62	
		46
70	8.85	
		48
75	9.09	
		44
80	9.31	
		44
85	9.53	
		42
90	9.74	
		44
95	9.96	
		44
100	10.18	
		42
105	10.39	
		42
110	10.60	
		40
115	10.80	
		44
120	11.02	
		40
125	11.22	
		44
130	11.44	
		40
135	11.64	
		42
140	11.85	
		40
145	12.05	
		40
150	12.25	
		33
153.3 T.D.	12.36	

TABLE 9.—Geothermal temperature gradient measurements for Tieton Willows drill hole, DNR-6A (date measured 9-15-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
5	10.89	
		-18
10	10.80	
		106
15	11.33	
		92
20	11.79	
		110
25	12.34	
		74
30	12.71	
		86
35	13.14	
		86
40	13.57	
		90
45	14.02	
		88
50	14.46	
		96
55	14.94	
		80
60	15.34	
		100
65	15.84	
		90
70	16.29	
		94
75	16.76	
		94
80	17.23	
		96
85	17.71	
		88
90	18.15	
		98
95	18.64	
		106
100	19.17	
		90
105	19.62	
		94
110	20.09	
		92
115	20.55	
		96
120	21.03	
		94
125	21.50	
		96
130	21.98	
		96
135	22.46	
		94
140	22.93	
		94
145	23.40	
		94
150	23.87	
		79
153.4 T.D.	24.14	

TABLE 10.—Geothermal temperature gradient measurements for Trout Creek drill hole, DNR-7 (date measured 9-10-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
10	7.52	46
15	7.75	76
20	8.13	84
25	8.55	72
30	8.91	74
35	9.28	64
40	9.60	66
45	9.93	80
50	10.33	86
55	10.76	76
60	11.14	86
65	11.57	90
70	12.02	90
75	12.47	86
80	12.90	100
85	13.40	76
90	13.78	80
95	14.18	90
100	14.63	80
105	15.03	94
110	15.50	78
115	15.89	100
120	16.39	86
125	16.82	92
130	17.28	90
135	17.73	84
140	18.15	90
145	18.60	90
150	19.05	45
154 T.D.	19.23	

TABLE 11.—Geothermal temperature gradient measurements for Carson drill hole, DNR-8 (date measured 9-14-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
5	9.87	-42
10	9.66	108
15	10.20	94
20	10.67	48
25	10.91	82
30	11.32	60
35	11.62	458
40	13.91	870
42	15.65	-100
43	15.55	-815
45	13.92	-62
50	13.61	106
55	14.14	122
60	14.75	114
65	15.32	102
70	15.83	58
75	16.12	-2
80	16.11	310
85	17.66	468
90	20.00	452
95	22.26	354
100	24.03	358
105	25.82	268
110	27.16	200
113.2 T.D.	27.80	

TABLE 12.—Geothermal temperature gradient measurements for Klickitat drill hole, DNR-9 (date measured 9-14-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
5	13.95	-46
10	13.72	-26
15	13.59	182
20	14.50	86
25	14.93	84
30	15.35	26
35	15.48	22
40	15.59	28
45	15.73	42
50	15.94	90
55	16.39	262
60	17.70	48
65	17.94	-40
70	17.74	46
75	17.97	46
80	18.20	50
85	18.45	52
90	18.71	58
95	19.00	48
100	19.24	52
105	19.50	44
110	19.72	86
115	20.15	-19
119.8 T.D.	20.06	

TABLE 13.—Geothermal temperature gradient measurements for City of North Bonneville No. 1 drill hole, NB-1 (date measured 5-1-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
0.0	18.22	-236
3.1	17.50	-2623
6.1	9.50	-200
9.1	8.89	-72
12.2	8.67	36
15.2	8.78	36
18.3	8.89	0
21.3	8.89	0
24.4	8.89	16
27.4	8.94	39
30.5	9.06	0
33.5	9.06	16
36.6	9.11	72
39.6	9.33	56
42.7	9.50	72
45.7	9.72	56
48.8	9.89	56
51.8	10.06	0
54.9	10.06	88
57.9	10.33	56
61.0	10.50	56
64.0	10.67	36
67.1	10.78	36
70.1	10.89	36
73.2	11.00	20
76.2	11.06	88
79.3	11.33	20
82.3	11.39	56
85.4	11.56	36
88.4	11.67	72
91.5	11.89	36
94.5	12.00	36
97.6	12.11	36
100.6	12.22	56
103.7	12.39	36
106.7	12.50	56
109.8	12.67	53
112.8	12.83	36
115.9	12.94	56
118.9	13.11	56
121.9	13.28	52
125.0	13.44	56
128.0	13.61	56
131.1	13.78	52
134.1	13.94	56
137.2	14.11	36
140.2	14.22	56
143.3	14.39	72
146.3	14.61	36
149.4	14.72	56
152.4	14.89	72
155.5	15.11	56
158.5	15.28	52
161.6	15.44	56
164.6	15.61	56
167.7	15.78	72
170.7	16.00	56
173.8	16.17	52
176.8	16.33	56
179.9	16.50	36
182.9	16.61	20
186.0 T.D.	16.67	

TABLE 14.—Geothermal temperature gradient measurements for City of North Bonneville No. 2 drill hole, NB-2 (date measured 9-11-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
5	12.16	-236
10	10.98	50
15	11.23	-90
20	10.78	-90
25	10.33	56
30	10.61	64
35	10.93	62
40	11.24	230
45	12.39	340
50	14.09	256
55	15.37	226
60	16.50	198
65	17.49	210
70	18.54	224
75	19.66	310
80	21.21	90
85	21.66	286
90	23.09	220
95	24.19	136
100	24.87	208
105	25.91	90
110	26.36	272
115	27.72	148
120	28.46	98
125	28.95	114
130	29.52	50
135	29.77	16
140	29.85	122
145	30.46	102
150	30.97	118
155	31.56	30
160	31.71	230
165	32.86	106
170	33.39	92
175	33.85	80
180	34.25	88
185	34.69	74
190	35.06	60
195	35.36	30
198 T.D.	35.45	

TABLE 15.—Geothermal temperature gradient measurements for City of North Bonneville No. 3 drill hole, NB-3 (date measured 9-11-81)

Depth (m)	Temperature °C	Geothermal gradient °C/km
10	11.50	70
15	11.85	86
20	12.28	62
25	12.59	98
30	13.08	138
35	13.77	132
40	14.43	158
45	15.22	182
50	16.13	130
55	16.78	156
60	17.56	114
65	18.13	146
70	18.86	142
75	19.57	56
80	19.85	76
85	20.23	94
90	20.70	82
95	21.11	86
100	21.54	86
105	21.97	112
110	22.53	102
115	23.04	94
120	23.51	76
125	23.89	82
130	24.30	112
135	24.86	98
140	25.35	86
145	25.78	68
150	26.12	52
155 T.D.	26.38	